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GREAT BASIN STATION

**-Sixty Years of Progress in
Range and Watershed Research**

Wendell M. Keck



USDA Forest Service Research Paper INT-118, 1972
INTERMOUNTAIN FOREST AND RANGE
EXPERIMENT STATION
Ogden, Utah 84401

ABOUT THE AUTHOR

Dr. Wendell M. Keck was publications editor at Intermountain Station for 12 years prior to retirement in 1969. During his editorship he became familiar with the Great Basin Station's physical features and the long, interesting history of important research done there. He gratefully acknowledges technical assistance in preparing this manuscript, particularly from Dr. William A. Laycock, A. Perry Plummer, Dr. James P. Blaisdell, and former Station Director Joseph F. Pechanec.

COVER PHOTO: Entrance to Great Basin Experimental Range headquarters.

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Forest Service
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ABSTRACT

Narrates briefly the history of the Great Basin Experimental Range from its establishment in 1912 as the Utah Experiment Station. Describes key problems in management of watershed and rangelands and the experiments devised to solve them, and indicates how results of this research have been applied in practice.

BEGINNINGS AND ESTABLISHMENT



Figure 1. — Original gate to Utah Experiment Station, 1914.

The Great Basin Experiment Station has been the headquarters for research on ecology and management of watershed and range-lands, as well as on problems of silviculture, ever since its creation in 1912 by administrative decision of Forester Henry S. Graves. The headquarters unit is located in an aspen grove on the west front of the high Wasatch Plateau in Sanpete County in central Utah at an elevation of 8,850 feet. The area of concern has always been broad. Station personnel have investigated and found solutions to special land use problems over a large part of the Great Basin and adjacent upper Colorado River Basin in Utah and Wyoming. The main field laboratory has been in Ephraim Canyon and adjacent drainages on the east side of the Wasatch Plateau. Applications of findings have been used widely in the West.

The Station has had several official names. It was first called the Utah Experiment Station (fig. 1). This name was changed to Great Basin Experiment Station in 1918 to end confusion with the name of the Experiment Station of the Utah Agricultural College at Logan. Each of these Stations had been receiving mail addressed to the other. This change of name was justified additionally by being more accurately descriptive of the extensive area the Great Basin Experiment Station served, which was far beyond the boundaries of Utah.¹

When the Intermountain Forest and Range Experiment Station was established on July 1, 1930, the Great Basin Experiment Station became a branch of it and was officially designated as the Great Basin Branch Station. C. L. Forsling, the Director of the Station, had proposed that the name of the unit be changed instead to the Wasatch Plateau Branch on the bases that (1) the Intermountain Station would absorb the old Experiment Station,

¹ The Great Basin Province designated by the U. S. Geological Survey includes most of the western half of Utah, nearly all of Nevada, California east of the summit of the Sierra Nevada, a large area in southeastern Oregon, and smaller portions of southeastern Idaho and southwestern Wyoming. Its 210,000 square miles include mountains, deserts, dry old lakebeds, a number of gradually receding lakes, of which the Great Salt Lake is best known, and innumerable fertile valleys and plains areas.

and (2) the work of this branch would, he thought, relate almost entirely to the high plateau regions, chiefly summer range of Utah. But Messrs. Clapp and Chapline, respectively Assistant Forester and Senior Inspector in Charge of Grazing Research, contended that the name Great Basin was well established after nearly 20 years' use and prevailed for retention of that part of the name. Validity of their judgment was amply confirmed because the continuing research at Great Basin Station has been concerned with environment far beyond the high plateau regions in Utah.

From Great Basin Branch Station, the name was changed to Great Basin Research Center; later still it became Great Basin Experimental Range, by which it is now officially known. Despite all these official changes in name, "Great Basin Station" popularly prevails and consequently is the name used throughout this history.

The impetus for establishing the Great Basin Station stemmed at least partially from numerous requests received by the Secretary of Agriculture by 1900 for scientific study of summertime floods that originated on mountain watersheds and were seriously damaging farms and rural communities in the West. Such floods, usually of mud and rocks, were especially severe and frequent in valley communities below the Wasatch Plateau in Sanpete and Emery Counties. As late as September 4, 1913, the Ephraim "Enterprise" headlined a front-page story "Flood Pays Annual Visit of Destruction." Dr. James T. Jardine, Inspector of Grazing for the U. S. Forest Service, energetically pushed for a western experiment station, and there had been plans for a station in the Blue Mountains of Oregon. The compelling reason for establishing the Utah Experiment Station was rooted in the precarious relation of many valley communities to the mountainside watersheds above them. Ephraim Canyon sustained several severe floods between 1889 and 1910. Manti Canyon, just a few miles south of it, flooded many times between 1888 and 1902. Following creation of the Manti Forest Reserve² in

1903, Manti Canyon was closed to grazing for several years, and no serious flood has come from it since 1902. An official report in the spring of 1910 attributed flooding in nearby canyons in 1909 to prolonged overgrazing. Reynolds (1911) reported a destructive flood in Ephraim on September 10, 1910, that left a thick layer of mud on the streets and filled irrigation ditches, culverts, cellars, and basements with debris. Grainfields west of the city were also damaged. So the need for determining the causes of summertime floods and for devising effective means of preventing or controlling them was compellingly evident.

■ Experimental Range Created

Since the problems of wildland management are varied, research has required use of numerous individual sites where certain specific characteristics of soil, terrain, climate, and vegetal cover were typical. A specific area for research in the drainage where the headquarters is located was long considered and used but was never officially designated until recently. On April 28, 1970, the Great Basin Experimental Range, comprised of 4,608 acres in Ephraim Canyon drainage, was formally set aside for range and watershed research by executive order signed by A. W. Greeley, Associate Chief of the Forest Service. The Great Basin Experimental Range is all within the Ephraim Ranger District of the Manti-LaSal National Forest and is chiefly in Ephraim Canyon. It occupies parts of 17 sections of Township 17 South, Range 4 East, Salt Lake Base and Meridian.

Although not large, this is an important piece of real estate. Additional acreage can be added to this experimental range as may be required. The present area will serve for future intensified research as well as for demonstrating the usefulness of findings.

The western boundary of Great Basin Experimental Range lies along the Manti-LaSal National Forest boundary and is at about 6,800 feet elevation. From there the northern boundary of the Experimental Range rises

² An Act of Congress approved March 4, 1907, changed the name "Forest Reserve" to "National Forest."

rather steadily to an elevation of about 10,300 feet at the Skyline Drive. This 3,500-foot rise occurs within a distance of about 4.5 airline miles, but some 10 miles by the Ephraim-Orangeville road. In traversing the Range, this road rises from the lower edge of Merriam's Transition life zone through the Canadian and Hudsonian zones to the Arctic-Alpine zone. Total annual precipitation increases from an average of 16 inches at Major's Flat (7,100 feet elevation) to about 40 inches at the summit. These four life zones and associated biotic communities, so close together and easily accessible, provide great diversity in plant species, soils, and climate, and thus give opportunity for convenient, efficient study of a wide variety of ecologically oriented problems of wildland management.

■ Site Selection and Buildings

The Utah Experiment Station literally had to be carved out of the wilderness. First-time visitors to the headquarters invariably ask: "How did this beautiful site happen to be selected?" Accounts of the actual selection vary. One states that about 1911 A. E.

Sherman (District Forester), Homer Fenn (Assistant District Forester), R. V. R. Reynolds (Forest Examiner), and a Mr. Hodson of the Manti National Forest set out to select a possible site for an experiment station. These four men and the narrator, A. W. Jensen, first supervisor of the Manti National Forest, drove up Fairview Canyon in a buggy to look at a site in the approximate location of the present Gooseberry Ranger Station, but they decided against it. They then drove up Ephraim Canyon to the area now called Bluebell Flat, but rejected it, as they did another proposed site farther up the canyon. As they were returning down the canyon, they turned off the road at the point where the Station is now situated and were immediately and favorably impressed with the site. James T. Jardine, then Chief of Experiment Stations in the Department of Agriculture, and Dr. A. W. Sampson, who was Chief Investigator of Range for the Department, concurred that the site selected was good.

Once the headquarters site had been selected and boundaries for the Station area had been determined, trees had to be felled, stumps pulled (fig. 2), land leveled, fences installed (to protect Station grounds and some experimental areas from being overrun by stock), and buildings constructed. Hence it is no surprise that Director Sampson's first annual report (December, 1913) of the Station's



Figure 2. — Clearing ground on west side of laboratory building, June 1914.

work devoted more than 20 pages to describing improvements already made and explaining additional improvements needed for the immediate future.

First construction was the Director's residence (now called the East House), a laboratory building, the Assistants' residence (fig. 3), and a barn. All these buildings except the Assistants' residence, which burned in 1935, are still standing and in good condition. The Assistants' residence was replaced in 1936 on the same site by an attractive dwelling now called The Lodge (fig. 4). It was a Civilian Conservation Corps (CCC) construction project and displays much excellent workmanship, including rooms attractively finished with knotty pine paneling. In time the need for a barn passed, and since 1955 the building has been a toolshed.

To promote varied studies in revegetation, a 17- by 40-foot greenhouse was built back of the office-laboratory building in 1913. It was divided into cold-bed and hot-bed compartments with separate heating and ventilating systems. The need for a greenhouse passed, and in 1933 the building was adapted for use as a dwelling for summer assistants and other temporary employees.

As scope of the Station's work broadened, more scientists and helpers were employed; this required building additional living quarters. A garage with dormitory facilities on the second story was built in the late 1920's. Summer employees nicknamed this structure "The Palmer House" after the famous Chicago hostelry. In 1933, in the early days of the CCC, two additional houses were built. The residence now called the End House was a few yards southwest of the Assistants' residences. The South House, originally designated as a dormitory, was built directly opposite the office-laboratory building and faces it. For many years the South House has been the locale for numerous training sessions and other meetings. Both the End and South Houses have two stories; the second floors have dormitory facilities.

After erection of these two buildings the Station headquarters area was landscaped in 1934 (fig. 5). An oval driveway lined with stones loops inside the area enclosed by the residence and office buildings. The flagpole was moved to the center of the oval, and the weather station was moved from the yard in front of the office-laboratory building to a convenient spot in the grass and shrub testing



Figure 3. — Main buildings, Great Basin Experiment Station, 1924. The Assistants' residence (left) burned in 1935 and was replaced by the Lodge in 1936.



Figure 4. — The Lodge at Great Basin Experimental Range, built in 1936. At extreme right is the west end of the original greenhouse, which was converted into a dwelling for summer assistants.



Figure 5. — Great Basin Branch Station yard after landscaping in 1934. Foreground area was later planted to trees and shrubs; center area now has native grasses, forbs, and shrubs.

area back of the End House. A picket fence and row of trees that had bounded the lawn in front of the first three houses were removed.

Water for the Station came from a large spring on the face of the cliff southeast of the residences. Since the spring is in a bed of limestone, the water was — and still is — very hard. Dr. Sampson recommended building a cistern to supply soft drinking and culinary water, but this was never done.

To keep horses within a convenient distance, a 50-foot corral was fenced off near the barn. Numerous other fences were built around the headquarters area and around smaller areas, such as the grass and shrub testing area, for protection against wandering stock (fig. 6). These fences were uniformly the rail-and-tie type, commonly called "log-and-block" fence. For the most part, these were built of aspen logs 16 feet long with a minimum diameter of 6 inches; ties were 30 inches long and 8 to 12 inches in diameter. Aspen suitable for this construction was plentiful and was chiefly used, but logs of conifer species were often intermixed. Many logs have had to be replaced, but the fences are still generally sturdy and effectively pro-

tect the Station from grazing by bands of sheep in the summer.

■ First Projects and Personnel

When the Utah Experiment Station was established, its number one task was to discover the causes of destructive summertime floods that originated on mountain watersheds; closely related, of course, was expectation that discovery of causes would suggest possible and feasible means for preventing them. Analysis of the watershed problem quickly revealed that problems of grazing and range management were inextricably related to it.

The initial research program at Utah Experiment Station included nine projects. Director Sampson's annual report of the Station for 1913 discussed them under the general headings of Grazing and Silviculture.

A study preliminary to the research on erosion included measurements of soil and air temperatures and of precipitation and soil moisture at three elevations throughout the



Figure 6. — A section of the aspen log fence that surrounds Great Basin Experimental Range and some smaller areas within it.

growing season. The highest weather station was at 10,000 feet, probably at or near the site of the present Alpine Station; the next lower one was at the Experiment Station headquarters at 8,850 feet; and the third was about 1,700 feet lower, near the present National Forest boundary at Major's Flat. These locations gave data for the Hudsonian zone (spruce-fir association), Canadian zone (aspen association), and Transition zone (oakbrush-aspen association). The records of temperatures, precipitation, and soil moisture, plus observations of the condition of vegetation, gave bases for measurement of the length of the growing season in the three life zones. They showed that the growing period in the Transition zone is about 3 weeks longer than that for the Canadian zone, and about 6 weeks longer than the growing season in the Hudsonian zone. Within 6 miles by wagon road, a scientist could encounter 6 weeks' difference in length of growing season.

Historical importance of the Great Basin Station can hardly be measured solely in terms of the numerous experiments performed there and their results, significant though they be. The Station has been a training ground for many men who later achieved prominent positions in the Forest Service and other governmental and academic positions. As long ago as 1939, Lincoln Ellison remarked in a talk at the Utah State Agricultural College:

Great Basin may be regarded as one of the two cradles of range research in this country. The other is Jornada Range Reserve in New Mexico. It is said that almost everybody in range research has, at one time or other, worked on the Jornada, and almost the same may be said of the Great Basin.

He named A. W. Sampson and F. S. Baker, who were then teaching at the University of California; W. R. Chapline, who had become Chief of Range Research for the Forest Service, and C. L. Forsling, who became head of the Division of Forest Research in Washington, D. C.; and C. F. Korstian, president of the Society of American Foresters and for many years dean of the School of Forestry at Duke University.

In an age that takes for granted the employment of numerous full-time personnel to staff any research organization, a reader is considerably surprised — if, indeed, not mildly shocked — to examine the personnel phase of the work at Utah Experiment Station. At the beginning, Director Sampson apparently was the only yearlong employee. In his annual report for 1913, he wrote:

During the active field season there were three temporary assistants and one permanent assistant. The temporary men were Messrs. William R. Chapline, Jr., who now has a permanent appointment in the Forest Service as Grazing Assistant, Richard O. Cromwell, and Paul H. Roberts.

He commented that Mr. Chapline's services began on June 1 and ended on November 15. The other two temporary assistants worked only short terms in the summer field season. F. T. McLean, who had been Forest Assistant on the Manti Forest prior to establishment of the Utah Experiment Station, was the "permanent" assistant until October 20, when he went on furlough. E. R. Hodson, also from the Manti Forest, succeeded him.

In the very first years, Mr. McLean was responsible for much of the experimental work in silviculture. His work was considerably augmented a few years later by that of F. S. Baker and C. F. Korstian, who were probing the mystery of the "pineless belt" (see Silvicultural Studies) in the brushlands of Utah and southern Idaho.

Director Sampson was favorably disposed toward using advanced forestry students as temporary summer assistants. He found them hard workers, eager to make good; they readily grasped the significance of the research and willingly accepted some hardships and long hours to promote the projects; and they could do hard manual work "quite as well as the theoretical." "For these reasons," he wrote in his first report, "I therefore strongly favor the employment of students to as great an extent as practicable in future seasons."

Prominent among the young men who worked at Utah Experiment Station in its early days was Leon H. Weyl, Grazing Assistant. He had completed his junior year in the

School of Forestry at the University of Nebraska when he was appointed Field Assistant in June 1914. Director Sampson highly praised his academic training, his rapid, accurate work, and his pleasing personality. Weyl's diaries for 1916 and 1917 record widely varied tasks: emptying precipitation tanks at Areas A and B, getting the snow stakes ready for winter measurements, working on the greenhouse roof, working on plant succession studies, taking photographs, mending the telephone lines, working on poison plant records, working on climatology computations — and many more. "Talking over work with Sampson" is a frequent entry. No wonder the Director liked young college men as workers! Mr. Weyl was coauthor with Dr. Sampson of "Range preservation and its relation to erosion control on western grazing lands" when the USDA Department Bulletin was published in 1918.

Salaries in the early days were unbelievably low. A. W. Jensen recalled, "To begin with, the rangers' salaries were \$60.00 per month for the short period they worked. I succeeded in getting them raised to \$75.00 before I left. They fed their own horses and received no expense money." In forecasting needs for 1916, Director Sampson listed his own salary at \$2,200, plus \$500 for expenses, and commented:

However, now that most of the construction work is well along, it is believed that the Director will be available personally to do an appreciable amount of experimentation, so that three assistants will suffice.

Temporary assistants for the summer field season were paid \$75 a month plus \$25 for expenses. A permanent Grazing Assistant was to receive \$1,200 per annum plus \$250 for expenses.

Another facet of life for Station personnel in the early days that startles modern-day em-

ployees was the parsimony with which supplies and ordinary office conveniences were supplied. This is graphically revealed in the following memorandum, dated November 29, 1927, from Director Forsling to the Operation Office of District Four in Ogden:

We are now entering upon the sixth year that the Great Basin Experiment Station has had offices in the District Office in Ogden. During all of this time we have been using office tables as substitutes for desks. Upon one or more occasions last year and the year before when some equipment from the Veteran's (sic) Bureau was available I made request of Mr. Pearson or the Maintenance clerk to consider the needs of the Station for double pedestal office desks. This was taken up again by memorandum or letter this fall. No desks have been received to date (sic). I understand that the unit of the Veterans Bureau at Salt Lake City has no more surplus desks.

At the present time it is necessary for Mr. Nelson and myself to keep papers and other material such as one will ordinarily keep in a desk tied in bundles or stacked in baskets and piled on top of a book-case unit we have. There are many other little conveniences that a double pedestal desk affords that we do not have. I think that the merits of our need are comparable with those of the average office. In all probability the headquarters of the Great Basin Station will be maintained in Ogden for a number of years and we hope permanently. I would appreciate it very much if early consideration would be given to the procurement of two double pedestal desks for use by the Great Basin Experiment Station if it is thought that procurement of such equipment for the Station is a legitimate thing for the District office to do.

THE WATERSHED STORY

■ Watersheds A and B

Among the officially designated studies, "Protection, Grazing vs. Erosion" was the longest continued and is best known today. This project was designed to determine, with considerable exactness, the relation of grazing and vegetal cover to erosion. It has been described and discussed extensively in the literature of watershed research as the studies of Watersheds A and B,³ which were first called "Erosion Areas."

The two Erosion Areas were established in 1912. Area A covers 11 acres and Area B covers nine. The two watersheds are about 900 feet apart and are at an elevation of 10,000 feet on a generally west-facing slope at the crest of the Wasatch Plateau. They are typical small watersheds in the Subalpine zone and were strategically established in an area where thousands of sheep had been trailed summer after summer, where oldtimers and valley residents averred that you could count the number of sheep bands on the mountaintop by the number of clouds of rolling dust on the horizon. Each is a complete watershed but neither one has a permanent stream. Soils on both Areas are residual clays and clay loams derived from limestone and shales. Average slope gradient of Area A is 18.5 percent; Area B's slope is 16.3 percent.

Annual precipitation averages 33 inches, but only about 4 to 6 inches come during the 3-month summer growing season; and this amount varies considerably from year to year. During most of the year, storms in this area are of low intensity; but in July and August they have a dramatically different pattern. They are brief, narrowly localized, and intense. Rainfall at the rate of 2.2 inches per hour for 20-minute periods has been recorded many times on both these watersheds, and such storms hit any given area on the Plateau at least once every few years.

Several things make these watersheds and their story outstanding. One is the length of continuous observation and study they have had. Another is the length of continuous cli-

³Details of description of these two Watersheds and their treatments are from Meeuwig (1960).

matic records for the studies — nearly 60 years by now. Vegetation has been surveyed periodically ever since 1912. Surface runoff and the resulting sediment have been measured since 1915, and summer storm intensities have been recorded since 1919. Continuous records of temperature and precipitation have been maintained on the Watersheds, at headquarters, and elsewhere on the Experimental Range. These long-term detailed records of climatic factors, of growth of vegetation, and of results of treatments applied to these two Watersheds constitute a tremendous mass of data. Interpretation of these data has had far-reaching significance, as will appear later.

The treatments of Watersheds A and B included manipulations of vegetative cover. When the studies began in 1912, vegetation on Watershed A had already been depleted to a 16-percent cover, whereas Watershed B had

about 40-percent cover. This condition was maintained by carefully controlled grazing through eight growing seasons, i.e., through the summer of 1919, so as to determine the amount of surface runoff and sediment production from a severely depleted watershed as compared to runoff and erosion from a watershed having fair plant cover. During that 8-year period Watershed A produced six times as much runoff and five times as much sediment as Watershed B, which was maintained with a 40-percent cover of vegetation. Preliminary results of the study were published by Sampson and Weyl (1918).

In 1920, cover on Watershed A was allowed to recover naturally by excluding grazing; within 5 years the vegetation built up to about the same 40-percent cover that Watershed B had in the beginning (fig. 7). During this period, Watershed A produced about

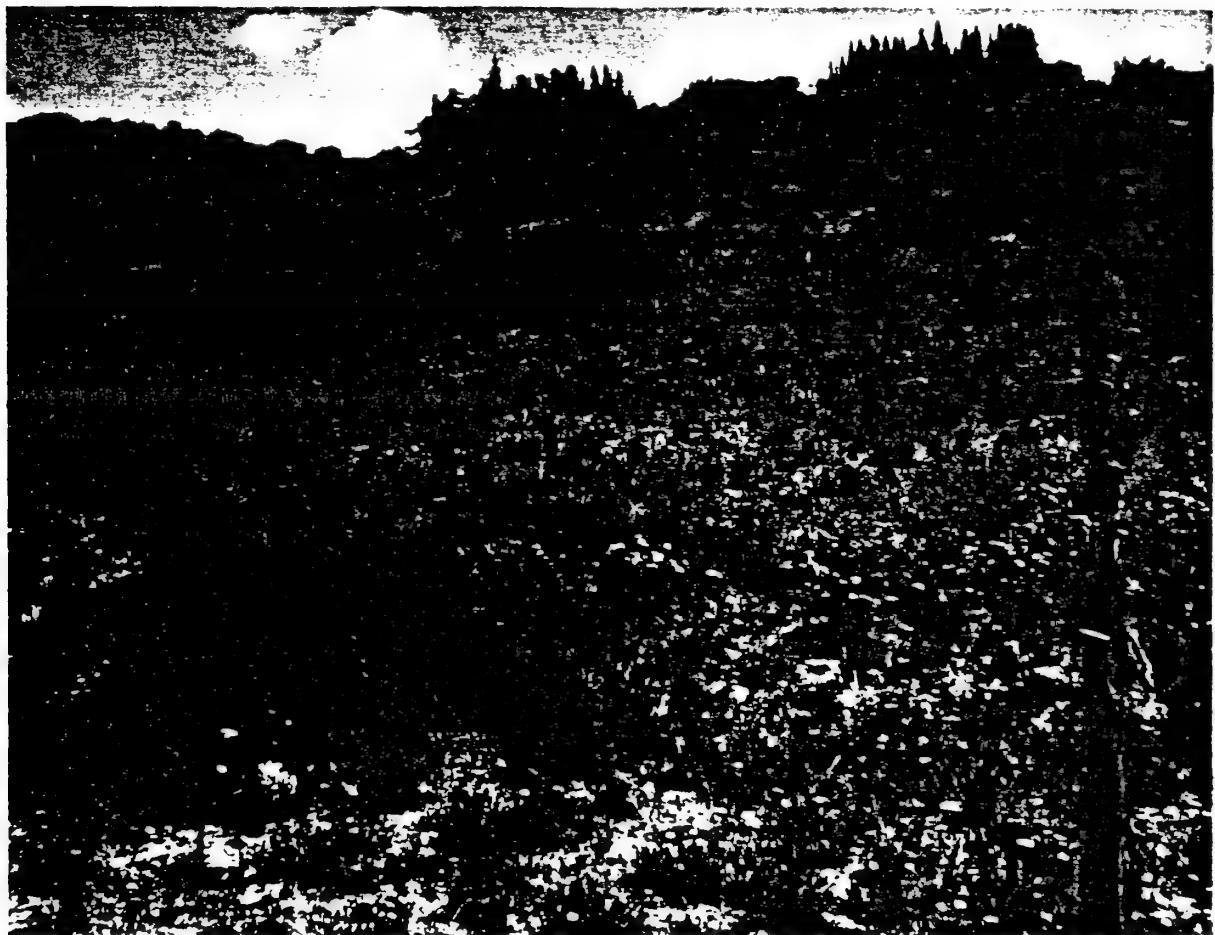


Figure 7. — Eastern boundary of Watershed A, 1970. Foreground shows small area of virtually bare ground, but most of the watershed is covered by grass, forbs, and shrubs.

three times as much runoff and sediment as Watershed B. From 1924 to 1930 average plant cover on both areas was about 40 percent. Watershed A, though, continued to produce about twice as much runoff and erosion as Watershed B, largely a result of a few bare spots. Results of the first two decades of study were published in 1931. (See Forsling 1931; Stewart and Forsling 1931).

From 1946 through 1951, vegetal cover on Watershed B was depleted to 16 percent by heavy grazing, and the watershed became a potential flood source. During this period Watershed B produced more than four times as much runoff and 12 times as much sediment as Watershed A. Late in 1952, Watershed B was artificially treated by disking, installing contour furrows on steeper slopes, and seeding a mixture of adapted grasses and some forbs. This restorative treatment completely transformed Watershed B. The disking and furrowing broke up the gully system that had formed when cover was sparse, and by 1954 an excellent stand of grass had become established over most of the area. Two major results of this artificial restoration of Watershed B have been: no summer storm runoff since 1953; and improvement of vegetal cover from a sparse stand of low-value broadleaf herbs to a good stand of palatable grasses. Sediment production on both Watersheds now is negligible.

Progress of the experiments on Watersheds A and B was not as smooth as the preceding narration may suggest. Director Sampson's report for 1913 recounted several annoying delays. For one thing, road conditions owing to abnormal summer rainfall were such that hauling a loaded wagon up Ephraim Canyon could be accomplished only at long intervals. Sand and cement for the bases of the steel sediment catchment basins for the two Watersheds had to be hauled from Ephraim, more than 10 miles away and approximately 5,000 feet lower. The first sediment catchment basins were made from sheet steel and provided with weirs. They were roughly 12 feet long, 5 feet wide, and 5 feet deep. Director Sampson had assumed that these basins would be large enough to allow the sediment in the water caught on each watershed to settle sufficiently to get a measure of the total silt. But

he was in for a bad time. On September 1, 1913, just after the sediment basin on Area A was installed, 0.17 inch of rain fell within a very few minutes. The tank filled in approximately 2 minutes after the full stream reached it, but the water kept pouring in for another 15 minutes; he reported, "It would have taken at least eight tanks to have held the water and silt which passed over the weir in Erosion Area A." Another shower 2 days later further demonstrated the inadequate size of the tank; so substantially larger concrete sediment catchment tanks for both Areas were built in 1914 (fig. 8).

It is difficult for the uninitiated to visualize what the sediment catchment tanks revealed until reading a statement by Director Sampson written in 1919.

Seeing, of course, is believing, but if anyone had told me that as much as a car load, or approximately 50,000 pounds of air dry dirt and rock would be deposited from a ten acre area from a single storm I would probably be inclined to ask permission to examine the figures for myself. Nevertheless air dry sediment of from 20,000 to 50,000 pounds has been deposited several times during the six years from a single rainstorm.

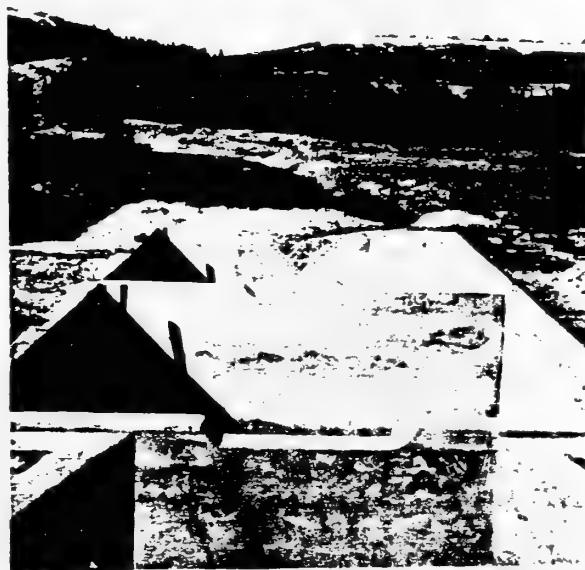


Figure 8. — Concrete sediment catchment tanks built at low corner of Area A in 1914.

With such volumes of erosion occurring year after year, it is no wonder that the range on the crest of the Wasatch Plateau was seriously depleted, that areas of bare rock appeared frequently, or that floods to the valley had been growing progressively more destructive.

The studies on Watersheds A and B have shown conclusively that summer floods are a direct result of reducing plant cover below minimum amounts required to prevent excessive runoff from high-intensity summer storms. Where vegetal cover has been severely depleted, it is often necessary to resort to contour trenching and seeding to restore satisfactory watershed conditions. Because of the success of this early work, few persons in valley towns today can remember any destructive summer flood roaring down from the mountaintop.

Little active watershed research is currently being carried out at the Great Basin Station. A few climatic stations and rain gages still collect records of physical factors, and the sediment basins and weirs on Watersheds A and B are being maintained. These records will provide the necessary background for any future watershed work that may be done on the area.

■ Infiltrometer Research

The treatments applied to Watersheds A and B produced significant information about the cause-and-effect relations of vegetative cover to storm runoff and soil erosion. However, Sampson and others recognized that treating instrumented watersheds was not the only useful way to study problems of the hydrology of rangelands. Several investigations at the Great Basin Station used rainfall-simulating infiltrometers, devices to apply artificial "rain" to plots at predetermined rates. Water and soil washed from the plots are collected and the amounts of water retained by the soil are calculated. In this way the hydrologic effects of a wide range of soil

and vegetative cover conditions can be studied, as well as their effects on runoff and erosion from different intensities and amounts of rain.

The major infiltrometer studies were conducted on an area seeded to introduced grasses in 1952 at the head of Manti Canyon and on adjacent unseeded areas. Three years after seeding there were no differences in soil stability, infiltration capacity, and soil bulk density between seeded and unseeded areas (Orr 1957). However, 7 years after seeding, differences were significant (Meeuwig 1965). The seeded areas had less capillary pore space and greater bulk density in the surface layers of soil. This indicated that, while disking and seeding effectively increased growth of forage on deteriorated subalpine ranges, these treatments should be used cautiously on areas that are in good condition because they can, at least temporarily, detrimentally affect infiltration and soil stability by reducing cover, soil organic matter, and soil porosity.

Meeuwig also found that grazing significantly affected relations between plant cover, soil, runoff, and erosion. The grazed plots had significantly less protective soil cover, less noncapillary pore space, more capillary pore space, and more runoff and soil erosion than the ungrazed plots. Conditions needed for high water retention and soil stability under heavy rainfall were found to be one or more of the following: (1) bulk density of surface 4 inches less than 0.97, (2) protective cover of litter and vegetation at least 85%, or (3) noncapillary porosity of the surface 4 inches of soil of at least 22 percent. If all of these conditions are considered, then the protection requirements in terms of each factor become somewhat less stringent.

■ Shrub Plantings

A second experiment that was part of the early watershed story was a project for planting cuttings and sprouts of aspen (*Populus*

tremuloides),⁴ native willow (*Salix* spp.), mountain elder (blackbead elder — *Sambucus racemosa* ssp. *pubens* var. *melanocarpa*), wild currant (*Ribes* spp.), and other promising shrubs in areas at the heads of mountain streams. The object was to determine practicability of trying to check erosion at the heads of streams and thus prevent floods at the point where they usually started.

Dr. Sampson laid out five plots at heads of three creeks and planted some 3,600 cuttings in June and July 1913 with crowbar and mattock. His report on the experiment is replete with accounts of details that should have been handled differently: dates for cutting and planting, treatment of cuttings before planting, and numerous others. Long periods of dry weather hampered growth, and snows came early that fall. Some cuttings were in poor condition when planted. Since the experimental planting plots could not be fenced, livestock trampled many cuttings. Generally, the cuttings of aspen and elder performed very poorly, but willow cuttings usually grew satisfactorily.

The report of this shrub-planting experiment closed with plans for continuing it the following year, with numerous changes in procedure. New Canyon had flooded seriously in August that year, much of the newly built road was destroyed, and many lawns in Ephraim were covered with silt and debris. So there was plenty of incentive for trying to find means of preventing further serious erosion of gullies near the heads of streams.

A report on this project at the end of 10 years⁵ stated that the initial plan of planting and seeding parallel to gullies proved ineffective and that the terrace plan of planting and seeding had been resorted to. Wild currant,

yellowbrush (*Chrysothamnus viscidiflorus*), and snowberry (*Symporicarpos oreophilus*) failed to become established; but blue foxglove (*Penstemon rydbergii*), sweetsage (*Artemisia michauxiana*), yarrow (*Achillea millefolium* spp. *lanulosa*), slender wheatgrass (*Agropyron trachycaulum*), mountain brome (*Bromus carinatus*), bottlebrush squirreltail (*Sitanion hystrix*), timothy (*Phleum pratense*), smooth brome (*Bromus inermis*), and Kentucky bluegrass (*Poa pratensis*) performed fairly well. This report stated further that considerable planting and seeding had been done on Watershed A and that the vegetative cover had improved appreciably as a result. Native turf-forming grasses were spreading well, but cultivated grasses did not produce viable seed. Plants with taproots were less satisfactory than plants with lateral-type roots. "The experiment," said the report, "has proven that erosion can be controlled by planting and protection against grazing without exorbitant cost but the treatment necessary is justified only on watersheds of very great importance."

■ Induced Snow Drifting

Early in the 1900's there had been some local interest in the possibility of "trapping" snow near the summit of the west side of the Wasatch Plateau as a means of prolonging spring snowmelt and thereby increasing the supply of water for summertime use in the valley. Many persons had observed that clumps of subalpine fir trees near the summit effectively caused drifts that persisted for 2 to 3 weeks after undrifted snow nearby had all melted (Lull and Orr 1950). In September 1947, H. W. Lull and H. K. Orr built four snow fences, each 50 feet long, in the headwaters of the Left Fork of Ephraim Creek. Measurements in the spring of 1948 showed that the 7-foot fences had been ineffective. The 11-foot fences, though only half as high as the average natural tree barriers, had produced a drift that contained about 70 percent

⁴ To avoid confusion of nomenclature, all scientific names are the current correct names as listed by Arthur H. Holmgren and James L. Reveal (*Checklist of the vascular plants of the Intermountain region, USDA Forest Service Research Paper INT-32, 160 p., illus. 1966*). Common names are those published in *Standardized Plant Names* except for a few common names in use at the time of publication.

⁵ Grazing investigative program. (On file at Great Basin Experimental Range.) 1923.

as much water and lasted about 70 percent as long after disappearance of undrifting snow as the drifts formed back of clumps of fir trees.

In 1957, Meeuwig continued and extended the study of inducing snowdrifts. A drift induced by a 16-foot snow fence was 15 feet deep and contained 100 cubic feet of water per lineal foot of fence whereas adjacent undrifting snow was only 8 feet deep. The induced drift persisted 10 days later into the

summer than the undrifting snow, and average water content along the main axis of this drift was 13 inches. Meeuwig's results were promising, but shifts in personnel and program emphasis prevented any further work on snow drifting at the Great Basin Station. The Rocky Mountain Forest and Range Experiment Station has subsequently done considerable additional research on induced snow drifting.

■ Depleted Range

Early studies at the Station had demonstrated that Ephraim Canyon's summertime floods were caused by depletion of high-elevation watersheds. Analysis of the watershed problem quickly revealed that problems of range management and grazing practice were inextricably related to it. How had this upland range come to deteriorate to such poor condition?

Settlement of the Sanpete Valley began about 1850, and the following 30 years saw a steady increase in the production of cattle and horses. Extensive and excellent summer range was available on the mountains and was free. Just as the range cattle business reached a peak about 1880, the sheep business began to take hold. Sheep were more profitable for anyone who could obtain enough summer range for them; so there began a bitter struggle between sheepmen and cattlemen. Tactics employed by both sides proved detrimental to the range, and its carrying capacity diminished rapidly. Reynolds (1911) graphically reported the outcome of the range battles:

The result was that, between 1888 and 1905, the Wasatch Range, from Thistle to Salina, was a vast dust bed, grazed, trampled and burned to the utmost. The timber cover was reduced, the brush thinned, the weeds and grass cropped to the roots, and such sod as existed was broken and worn. The basins at the head of the canyons suffered most, relatively, because they contained the best feed for sheep and were less broken in topography and more easily accessible. Their scanty timber cover, however, made them particularly liable to removal of the soil by wind action wherever the surface cover was broken through and the dry powdered earth exposed. These high mountain pastures, therefore, received not only the most abuse, but have been proportionately longer in recovering from its effects.

It is no wonder that Sampson and his early colleagues found that the mountaintop range

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areas suffered from two types of serious damage, both resulting from prolonged abuse of the land: valuable forage species had been killed out, and several inches of topsoil had been washed or blown away; this left an erosion pavement of comparatively unproductive soil and rock. Of these two types of damage, the loss of topsoil was the more serious because without it reestablishment of vegetation for forage and soil stabilization was difficult.

Before a decade of the sheep era had passed, the mountain range areas had been damaged so seriously that the era of summertime floods began. No serious flood had been reported from any canyon in this area prior to 1888, but serious floods occurred in Ephraim Canyon and other canyons in the area in nine seasons between 1888 and 1910. The history of flooding in other canyons along the Wasatch Front during that period was similar. Even in Castle Valley on the eastern side of the mountains, the story was the same: agricultural and business properties were destroyed and fish in the mountain streams were killed.

By the end of 1901, the situation in Sanpete County was becoming desperate. In March 1902, a large area on Manti Mountain was withdrawn from entry, and on May 29, 1903, President Roosevelt created the Manti Forest Reserve by proclamation. Less than 5 months later, the Commissioner of the Land Office ordered all sheep removed from the western slope of the mountains before the start of the following grazing season. He also ordered the supervisor of the Forest Reserve to prohibit all grazing of cattle, horses, and sheep on some 8,830 acres in the uplands of the several forks of Manti Canyon. This strict closure was in effect for five grazing seasons.

The drastic action paid off: Manti Canyon has had no serious flood since August 1902 (Reynolds 1911). Seven years later, both Ephraim and Six Mile Canyons, which had been overgrazed for 20 years after 1882, were flooded severely; but Manti Canyon was not affected. In 1909, after representations by many stockmen, the Forest Service permitted grazing in the area by cattle and horses at the rate of one head for each 30 acres, or a total of about 300 head.

■ Searching for Better Range Management

Temporary exclusion of stock from mountain rangelands was all very well as an emergency measure, but the Utah livestock industry could not tolerate the locking up of high-elevation summer range as a permanent arrangement; so the stockmen began to put pressure on Forest officers to permit summer grazing on National Forest lands. Forest officers were thus caught between their responsibility to care for the rangelands within their jurisdiction and their understandable concern for the welfare of the stockmen. From all the confusion and turmoil, though, one idea emerged with increasing force and clarity: better grazing management was necessary both for preservation and improvement of the rangelands and for continuation of the livestock industry.

Development of satisfactory grazing practices on public lands has been beset by numerous and varied problems. Fundamental was development of a program that would give vegetation the greatest chance to grow consistent with the profitable handling of large numbers of livestock. From the beginnings of range research, many workers have felt a strong sense of urgency. This has resulted partly from realization that millions of acres had been seriously depleted and that other millions of acres were constantly threatened; but many persons did not — and still do not — realize that depletion usually is an irreversible process; so they optimistically assumed that areas damaged by overgrazing, trampling, and erosion could eventually be restored to their original maximum productivity. But the unpleasant fact is that topsoil once lost is lost forever.

The question of "range readiness" for grazing has long been thorny. Many stockmen thought — some still do — that range was ready for grazing when new growth of grass amounted to no more than 2 or 3 inches. But study of life histories of many grasses demonstrated that these key species should have about 6 inches of new growth before stock

are permitted to graze them (Sampson and Malmsten 1926). This headstart of growth of plants was especially important because, at that time, livestock grazed the range continually once they entered. This initial growth became less important with the advent of rotation grazing schemes in which any given area of the range is grazed during only part of a grazing season, and is grazed at a different time each year. Related questions in the early studies were how long stock should be permitted to remain on range and how fully forage plants should be utilized.

James T. Jardine, Inspector of Grazing for the Forest Service, was among the first to state that the condition of animals was not in itself a safe way to judge whether a range was overstocked (Jardine 1916). In 1915 he wrote that "it had been common practice on privately owned land to put on all the livestock that the range would carry and turn them off in fair to good condition, in the belief that if they came off in satisfactory shape the range was not overstocked or injured." He commented: "This is true, provided the season of grazing is limited so as to give the vegetation a chance to do more than merely produce a few leaves, which are eaten as soon as they are long enough to crop." He admitted that this theory worked well enough on winter pastures that had been protected during their growing season, and on National Forest ranges where stock were not allowed to graze until vegetation was well along in its growing season, and on some spring-fall range. But, he concluded: "It does not work . . . where the stock are on the pasture to its apparent capacity during all or the greater part of the growing period of the main forage plants. When this is the case the number of stock must be reduced materially below the number which can be kept in good condition, if the pasture is to be kept up."

Against active opposition the Forest Service has stoutly maintained for more than half a century that the condition of plants and soils is the only sure way to judge condition of a range. Intensive studies of plant behavior and soil conditions have confirmed this stand. In discussing proper utilization, Jardine stated categorically:

When the season of grazing that will give the vegetation the greatest chance to

grow, consistent with the profitable handling of the stock, is decided upon, then, and not until then, can the number of stock a given pasture will carry be consistently estimated. It should be determined finally by careful observation of the range, not the stock, over a period of from 3 to 5 years.

■ Revegetation

In 1913, even though experiments had not yet demonstrated relationship between summer floods and the denuded high-elevation rangelands, many presumed some such relation existed. Furthermore, increased production of forage obviously was needed. Hence, an urgent initial problem for the Utah Experiment Station was how to rehabilitate depleted range areas if, indeed, restoration were possible. This problem seemed susceptible of two solutions: natural seeding by native species, and direct seeding with natives or exotics. Assuming that either or both of these treatments were feasible, other questions had to be answered. If rangelands could be seeded naturally, how should grazing be managed to assure maintenance of their improved condition? If direct seeding were to be resorted to, what species were best adapted to the high-elevation ranges; when should they be planted; what cultural methods should be adopted; and, assuming successful rehabilitation, how should these rangelands be managed both for their best maintenance and improvement and for providing needed forage for livestock and game?

Director Sampson believed wholeheartedly in the efficacy of permanent quadrats for studying change in vegetative cover; so he proceeded in 1913 to establish quadrats on the Two-Mile Strip in the Manti National Forest on the Wasatch Plateau (fig. 9). The Two-Mile Strip was an area 2 miles wide at the heads of canyons along the Divide on the Plateau where stock were not permitted until August 20, at which time the earlier forage plants would have



Figure 9. — Typical quadrat near the Two Mile Strip.

mature seeds. The Strip had been established about 1911 following strong urging by a committee of two sheepmen, two cattlemen, and a merchant representing the communities of Orangeville and Castledale in Emery County. This area, understandably, was in great need of improvement; hence quadrats were established here to determine to what extent the depleted lands were naturally revegetating. Some quadrats were on steep slopes; some were on comparatively level ground; some were on south-facing slopes; some on west-facing — harsh sites in either case; some were on moderately grazed areas; some on overgrazed; some on soils supporting fairly dense plant associations; others on sparse stands.

In the initial year, not much could be done beyond locating and marking the quadrats and photographing some for future comparisons. Even fencing had to be postponed until the following year. Director Sampson projected considerable expansion of this project for subse-

quent years, firm in the belief that the results would be used in management of depleted rangelands grazed by cattle and sheep. The very slow recovery of depleted mountain grazing lands was not yet realized; so he estimated completion of the project by 1918.

ARTIFICIAL SEEDING

Sampson recognized that natural seeding might not accomplish rehabilitation on overgrazed range adequately or quickly enough; hence his plan for experiments in direct seeding of denuded rangelands. The threefold objective was to determine which species were best adapted to local conditions, what time of the year was best for seeding, and what cultural methods should be employed.

In the autumn of 1912, two experimental areas, each with two plots, were planted to timothy, Kentucky bluegrass, orchardgrass (*Dactylis glomerata*), and smooth brome. One

of these areas was one-half mile south of Seeley Creek Ranger Station; the other was on Philadelphia Flat. They represented typical sites in the Hudsonian zone on both sides of the summit of the Wasatch Plateau. Fairly satisfactory stands were obtained the first year for all species but orchardgrass. On the Seeley Creek area, sheep were herded over the area to trample the seed into the ground (fig. 10), but on Philadelphia Flat a mechanical harrow was used. White sweetclover (*Melilotus alba*) and red clover (*Trifolium pratense*) were also planted but did not produce satisfactorily at these high elevations.

One useful result of the first year of this experiment was learning that wherever the native "bluebell" (*Penstemon rydbergii*) grew well, one could expect a good stand of Kentucky bluegrass. Results at Seeley Creek were better than those at Philadelphia Flat because the latter was a favorite bedground for cattle. To determine the nature and extent of loss of seedlings, quadrats were established for ex-

tended observation. Also, at Seeley Creek, a small part of the range was fenced to determine how well vegetation would succeed under complete protection as compared with vegetation that was subject to annual grazing by sheep.

A related project experimented with species, most of them native, that promised to be adaptable to ranges where they did not naturally occur. The species were: white sweetclover; Idaho fescue (*Festuca idahoensis*); showy oniongrass (*Melica spectabilis*); bearded bluebunch wheatgrass (*Agropyron spicatum*); biscuitroot (*Lomatium dissectum*); clover (*Trifolium spp.*); and sweetanise (*Osmorhiza occidentalis*). Despite great care in cultivation, the seed of the fescue, biscuitroot, and sweetanise did not germinate; but the others, to quote Director Sampson, "showed good field germination, and the stand at the end of the season was as good as might be expected."

Research in range seeding continued at Great Basin Station during the 1930's and 1940's; these studies especially emphasized



Figure 10. — Sheep "harrowing" seed after broadcast sowing on open area near the head of Seeley Creek.

species adaptability, methods and season of planting, and reduction of competing vegetation. Substantial progress during this period developed suitable procedures for many large-scale projects in range revegetation and also the background for important later research. Contributions by A. Perry Plummer and Neil C. Frischknecht were especially important.

Reorganization within the U. S. Department of Agriculture resulted in transfer of certain range research projects and employees from the Forest Service to the Agricultural Research Service in January 1954. Research on range seeding for domestic livestock was continued at Great Basin Station by William J. McGinnies. Emphasis was on fertilizing and methods of planting to increase stand establishment. This work has been continued at Great Basin Station by A. T. Bleak since 1956, primarily in studies of germination of grasses and forbs under winter snow, and on winter mortality and longevity of seeded species.

Following the 1954 reorganization, the Forest Service retained research projects in range seeding that were related to protection of watersheds and improvement of big-game ranges. Research by the Forest Service prior to 1954, and that of both the Forest Service and the Agricultural Research Service after that date, formed the basis for up-to-date procedures for restoration of depleted ranges in the Western States (Plummer 1943; Bleak and Plummer 1954; Plummer and others 1955, 1959, 1968; McGinnies 1959; Bleak 1968; and many others). As a result of these investigations more than one hundred species, both exotic and native and about equally divided among grasses, forbs, and shrubs, are being successfully planted today on western ranges.

Of special importance, researchers found that merely broadcasting seeds of adapted species in depleted aspen, Gambel oak, or choke-cherry stands at leaf fall resulted in productive stands of herbaceous plants. In many areas, especially on mountain ranges, association of shrubs with herbs or aspen trees resulted in as great, and often greater, production of herbaceous plants as where the shrubs and trees had been eliminated or where they did not naturally occur. This is somewhat paradoxical because on many ranges covered by more competitive plants it is necessary to reduce their

competition considerably by brushland plowing, anchor chaining, or some similar technique. However, seeding these ranges to adapted species by airplane or drills in the fall or winter results in good stands. These procedures are now widely used throughout the West.

Further development and improvement of western ranges by artificial planting continues as an important part of the research program at Great Basin Station.

GAME RANGE RESTORATION RESEARCH

Much of the research at the Great Basin Station since 1955 has been in the game range restoration project sponsored cooperatively by the Utah Division of Fish and Game and the Intermountain Forest and Range Experiment Station.⁶ This research has been necessarily directed toward a variety of related problems: What range areas were in critical condition? What kinds of game range could be improved? What species of grasses, forbs, and shrubs were adapted for use in restoration and improvement treatments? What techniques of land treatment and planting were effective and feasible? And a host of others. Research was directed chiefly toward restoration of winter game range, but summer range at higher elevations was also considered. The winter ranges are critical because large numbers of mule deer and elk depend on them for winter forage.

The complexity of the necessary research is suggested by the varied character of the environment. Some areas of winter range in the salt-desert shrub type receive less than 8 inches of rainfall annually, whereas precipitation on some summer ranges varies from 30 inches at lower altitudes to 60 or more inches near mountaintops. Likewise, length of the growing season varies from an average of 120 days in the oakbrush type to only 70 days in the spruce-fir

⁶For a comprehensive account of the problems, procedures, and results of the first 13 years' work on this project, see Plummer and others (1968). For yearly reports on separate phases of this work, see the series titled "Job Completion Reports for the Game Forage Revegetation Project" issued by the Utah Division of Fish and Game (now Utah Division of Wildlife Resources) since 1956.

type. Terrain varies from fairly flat to steep; fertility of soil also varies greatly. Most soils over the State, derived from a variety of sedimentary rocks, have a basic reaction; but soils in some game ranges, notably in the Uinta, Tushar, and Mineral Mountains, are acid. Competing vegetation (e.g., pinyon pine and juniper) makes artificial revegetation extremely difficult.

Some game range areas are covered by dense thickets of Gambel oak. Most foothill areas are favorable environment for juniper and pinyon pine trees, which choke out grass or forb understory; this type offers much opportunity for improvement. Since thousands of acres in Utah are wildlands dominated by this type and can be considerably improved for use by both game and livestock, the significance of this research can be appreciated easily.

Intensive initial trials of forbs, shrubs, and grasses, and of planting techniques have been conducted in Ephraim Canyon at elevations of 5,700 and 7,200 feet; these elevations are the lower and upper edges of big-game winter range and are also the approximate borders of the pinyon-juniper type. In addition, numerous species of grasses have been tested in plantings on the Wasatch Plateau at more than 10,000 feet. Species that show promise of adaptability have been tested further at more than 50 outlying sites scattered over the State. This research has emphasized study of shrubs and forbs because comparatively little information about these classes of plants had been developed and published, whereas the study of grasses has been extensive and the volume of available information about them is correspondingly large.

Besides studying adaptability of plant species, this cooperative project has studied means for improving efficiency of methods for reducing plant competition and for effective systems of planting seeds, seedlings, wildlings, and other materials. Chaining, cabling, burning, disking, and pipe harrowing have been tested to determine which treatment provides best site preparation for typical problem areas. For direct seeding, conventional drilling, drilling with scalpers, tractor dribbling, and broadcasting with and without covering have been tried. Seedings in autumn, winter, and spring have been compared for effectiveness.

This project has been directed by A. Perry Plummer, a career Forest Service range scientist, with active assistance from Biologists Homer Stapley, Donald R. Christensen, Stephen B. Monsen, Richard Stevens, and Bruce Guinta of the Utah Division of Wildlife Resources. Results have been substantial. Successful restoration programs have been completed on more than 120,000 acres within the State. An important feature of this project is the unusually early use of results of this research. Treatments developed by this project have been so successful that several other public land managing agencies in Utah and neighboring States have adopted them or used them with minor adaptations. Annual Job Completion Reports published by the Utah Division of Wildlife Resources report ratings of performance of more than 300 species of shrubs, forbs, and grasses (Plummer and others 1970); this is a selection that has survived from initial testing of more than 3,000 species and variants. Likewise, studies of germination, of techniques of site preparation and planting, of protection of plantings against the ravages of small mammals, and of changes of ground cover after eradication of pinyon-juniper stands are continuing.

■ Plant Vigor Studies

Early studies of rangeland and its management continually raised questions about plant characteristics that had never been answered. Effective planning of range management requires knowledge of plant vigor and the factors that contribute to it. The implicit question that stimulated numerous early research projects was: how intensively and how frequently can a given area (or species) be grazed but still maintain or improve the condition of the range? This question prompted the initial studies of natural revegetation of depleted areas and the studies of artificial seeding. From these developed another group called the Plant Vigor studies, which were directly related to the question stated above.



Figure 11. — General view of part of the forage nursery where early studies of plant vigor were made.

Development of desirable grazing technique requires answers to such questions as: How early can the range be grazed? How many times within a growing season can it be grazed? How completely may plants be utilized and still have the range maintained and improved?

The first plant vigor experiments were started at the Station headquarters in the autumn of 1916 (fig. 11). For one experiment, three species that had produced well and had recovered satisfactorily from grazing were studied; namely, mountain brome, smooth brome, and slender wheatgrass. The experiment was designed to determine just how different intensities and different frequencies of grazing affected the seasonlong growth and vigor of these valuable grasses. Thirty specimens of each species were planted in each of four plots. Harvesting varied from one to four times during the growing season.

Plots where herbage was removed four times during the season produced the least dry matter, and plants were seriously weakened; plots harvested twice produced the second least amount of dry matter, and plants were some-

what weakened. Plots cut just before seed maturity generally showed the greatest production of dry matter and best plant survival.

A companion project studied nine species: five grasses, three forbs, and one shrub. To obtain the most accurate data possible, the forage removed from all plots was harvested with shears "in a method simulating grazing as nearly as possible." The season and closeness of harvesting represented some 24 methods of harvest differing in date, frequency, and closeness of cutting.

In 1919 this project was expanded by planting numerous additional native forage species in the nursery. The following year, many new plots were set out on the range so that performance could be watched under actual range conditions. Some of these plots were in the oak-brush type (elevation 7,200 feet) and some in the spruce-fir type (about 10,000 feet).

These experiments and their results were reported in detail by Director Sampson and Harry E. Malmsten, Grazing Examiner, in a "landmark" publication (Sampson and Malmsten 1926). Published while the science of

range management was literally in its infancy, this bulletin provides unusually interesting reading today for layman and scientist alike.

These early studies in plant vigor stimulated increasing interest to learn how plants responded to grazing. This, in turn, generated great interest in study of life histories of numerous range plant species and in a phenomenal collecting of specimens for herbaria at the Station, at District headquarters, and in Washington. Indeed, at one time, the Manti National Forest had the reputation of being one of the most intensely botanized Forests in the Nation.⁷ Plant collections from the Experiment Station were numerous from the beginning through the 1940's and the correspondence between Lincoln Ellison and William A. Dayton and other taxonomists was voluminous. The plant collections and the resulting herbarium were very helpful in familiarizing both researchers and managers with the species on the range and their interrelationships.

When C. L. Forsling succeeded Sampson as Director of the Great Basin Station in 1922, interest in the plant vigor experiments was still running high. He believed the study should be continued but more nearly in line with actual grazing practice. Accordingly, he devised an experimental project in which sheep would graze a pasture until the forage had been utilized to a predetermined degree. Then the pasture would be allowed to recover. The grazing program was designed to match the 24 types of harvesting that had already been done with shears at the Station's forage nursery.

For this project Forsling selected a location at the head of the Cove Fork of Ferron Canyon, about 6 miles south of the Alpine Station. On a virtually level terrace about 100 feet below the present Skyline Drive and on the east side of the Divide, he laid out and fenced three contiguous 20-acre pastures (fig. 12). These were

⁷This statement was made in a letter by W. R. Chapline, dated April 8, 1924. He stated further: "The Washington Office records indicate that the first plant collection reached here from the Manti in September, 1912, so that collecting has taken place there for at least 12 years. Altogether we have record of 27 collections on the Manti, embracing 1365 specimens . . ."

called the Cove Paddocks. The sheep-grazing experiments began in 1923 and continued through several seasons. Fieldwork here virtually ceased in 1932 and the paddocks were later abandoned. Despite careful design and control of the grazing procedures and despite the fact that volumes of data were collected from several detailed reconnaissances and were elaborately analyzed, no publication about this project appeared. The slow response of mountain vegetation to treatment was still not recognized by these early researchers. If these experiments had been continued long enough, change in vegetation due to the treatments might have occurred.

■ Studies of Poisonous Plants

Presence of poisonous plants was at least a nuisance, at worst a plague on mountain range-land.⁸ Sometimes, poisonous plants fill in areas where desirable species have been killed off, especially by overgrazing. Great increase in poisonous plants is often a symptom of overgrazing. Some of these plants are unpalatable and are eaten only when animals are desperately hungry; thus they persist on ranges after associated nonpoisonous plants have been grazed out.

Since tall larkspur (*Delphinium barbeyi*) was a poisonous tall forb found most commonly on the Wasatch Plateau, Sampson designed a study to determine feasible methods for eradicating it. This plant starts growth each year from buds that sprout from the collar of the parent root; so Sampson theorized that if the aerial stems were cut at the right time — when the root contained the least stored food — it might sufficiently weaken the roots as reproductive parts so that the plant would die from lack of food and from the competition of neighboring healthy plants. Results of studies on plots Sampson established in 1913

⁸Earl V. Storm in 1919 reported annual losses of 6,000 cattle and 16,000 sheep within National Forests due to eating poisonous plants.



Figure 12. — Site of Cove Paddocks experiments near Skyline Drive.

near Seeley Creek Ranger Station showed that the growing plant stored its starchy food chiefly in its roots and collar. Grubbing the plants an inch or two below ground surface early in the growing season, before much food was stored, gave reasonably good control.

This study provided considerable information about food storage and the time of clipping that would produce greatest effect. Thus it furnished essential background for plant food reserve studies 20 years later by E. C. McCarty and Raymond Price (1942).

■ Relation of Grazing to Aspen Reproduction and Range Condition

Aspen dominates several million acres of high-elevation summer range in the Rocky Mountain and Intermountain areas, mostly between the mountain brush and subalpine conifer zones. When in good condition, the lush undergrowth in aspen furnishes considerable cover and forage for wildlife and livestock. The type also has esthetic value, some commercial value for certain timber products (e.g., excelsior), and is valuable for watershed protection. Studies on aspen here actually predated the establishment of the Great Basin Station. One study on the effect of grazing upon aspen reproduction (Sampson 1919a) was started in 1902 and dealt with management of grazing on aspen range, particularly on what effect sheep grazing had on reproduction and growth of aspen following clearcutting. The conclusions were that, to avoid destruction of aspen sprouts after cutting, three courses of action were available: (1) entire exclusion of grazing for 3 years; (2) exceedingly light grazing by sheep; or (3) moderate grazing by cattle. The height of the sprouts was found to be the main factor determining when reproduction was protected from destruction by livestock grazing. A surprisingly large proportion of aspen sprouts were killed during the first 3 years by causes

other than grazing; e.g., frost, and bark consumption by gophers, mice, and rabbits. Big game populations were quite low at the time these early studies were conducted; later research elsewhere has shown that deer and other game can also browse sprouts too heavily to allow aspen reproduction. Other factors, particularly competition from herbaceous vegetation, may also suppress aspen regeneration.

Interest in aspen range continued, and some 35 years later Jack Major (now at the University of California, Davis), Walter Houston (now with the Agricultural Research Service), and Lincoln Ellison, began a study designed to help managers assess the condition of aspen range (Houston 1954; Ellison and Houston 1958). Their study was concerned primarily with openings in aspen forest rather than with the aspen stand itself. They pointed out that openings are key areas, that they have more grass and forbs than the aspen stands and consequently carry the bulk of the grazing load. If the cover in these openings is kept in good condition, understory vegetation in the tree areas will also be good. Comparison of forage production under aspen canopy and in openings can aid in judging range condition.

Houston's criteria for judging the condition of aspen range included amount of cover, species composition, amount of current aspen reproduction, current production of all types of forage, and presence or absence of erosion. In evaluating species composition he gave highest rating to species that were tall, succulent, and palatable.

■ Plant Studies

ECOLOGICAL ENDEAVORS

Late in the 1960's countless Americans began to be aware of a complex of problems loosely labeled "environment." Some could be specifically classed as "pollution," but many others eluded classification. For the first time, many heard the word "ecology," and soon, without knowing precisely what the term meant, called themselves "ecologists" — and multiplied. Many of these new ecologists of the 60's and 70's are surprised to learn that Forest Service scientists, including ecologists, have been studying plants and animals in relation to their environment ever since the Utah Experiment Station was established in 1912. Indeed, the problem of destructive summertime floods from the high Wasatch Plateau was basically an ecological problem related to depletion of vegetation by grazing animals. This in turn posed the necessity for learning much about range vegetation and its interrelations with animals, soil, climate, and other environmental characteristics. This chapter briefly describes some of these projects and evaluates their results.

In applying the principle of plant succession to range management, Sampson noted two objectives to be kept in mind; namely, that herbage should be cropped at a time in its growing season when growth and reproduction would sustain minimum injury, and that the forage crop should be used when it was most needed and when it was palatable and nutritious (Sampson 1919b). He opined that plants could be grazed closely early in the season once in 3 or 4 years without danger and advocated the deferred-and-rotation grazing system which provided for this. Judicious grazing, in his opinion, disturbed vegetation cover only slightly.

Sampson's knowledge of range plants and their characteristics was already well developed when he arrived in Utah. He used knowledge gained in previous experience, notably in Oregon, in studying the complex range problems on the Wasatch Plateau. The extent and depth of this professional background are shown well in his Department of Agriculture Bulletin No. 4, "The Reseeding of Depleted Grazing Lands to Cultivated Forage Plants,"

published in 1913. Content of this Bulletin was based largely on his experiments in the Wallowa National Forest in the Blue Mountains. The Forest Service grazing studies in Oregon had been undertaken in 1907 as cooperative projects with the Bureau of Plant Industry.

The literature of early range research frequently repeats several questions: When is rangeland ready for grazing in the spring? How intensively should forage be grazed? When should grazing on mountain range stop in the fall? What species provide best nutrition for various classes of animals? How can we evaluate present condition of a range area? How can we tell whether a given area is improving or becoming further depleted? And many others. These questions were constantly in Sampson's mind and in the minds of his colleagues and successors.

Sampson's studies pointed the way toward answers to these questions, and his Bulletin on plant succession enunciated many useful principles. Forsling carried many of Sampson's inquiries further, but he inclined to test performance of individual species and different systems of grazing under actual field conditions rather than by the precise measurements that could be made in the laboratory, greenhouse, and nursery.

In 1938, Lincoln Ellison came to Intermountain Station and embarked on numerous and varied studies. The variety may be accounted for partly by the catholicity of his intellectual interests, partly by the fact that he regarded the range complex as an integrated whole.

Ellison was remarkably aware of the complexity of the range, of the problems incidental to its use, and of the numerous and contradictory opinions of persons who had studied them. One of his early publications at Intermountain Station (Ellison and Croft 1944) recognized existence of numerous contrary opinions about range and its use:

With the great divergences in opinion that exist at present, it is unlikely that the entire task of judging range condition and trend can be revolutionized overnight. Yet it is reasonable to believe that a careful appraisal of the elements making up mountain range, and an analysis of the sig-

nificance of the indicators commonly used in judging range condition and trend, will provide a basis in fact which will be one step toward more uniform agreement among range managers.

Ellison viewed range-watershed as a complex total comprised of biotic community, soil, climate, and topography — plus their interrelations; in short, he conceived the total as being something more than merely the sum of its parts, and an important constituent in this difference was what he called "balance," an element equated with the health of the range. He considered orderly successional change to be a normal condition of the range complex. This concept of balance of elements and health of range is implicit in the following statement of objective of range management (Ellison and Croft 1944, page 22):

The basic purpose in range management is to maintain the resource in such a condition that it will supply man with a maximum of the products and services he needs, or if the resource is already depleted, to restore it to that condition. The products for which satisfactory condition is to be attained are primarily water and forage, and in certain places there may be additional demands for timber or compliance with certain esthetic standards, depending on the use being made of the land. The purposes of range management, whatever they may be, require a combination of effective plant cover and stabilized, productive soil, and this combination must be sustained.

Beyond this, he believed that the best condition attainable for mountain range was likely to be much different from the optimum condition of range in a valley or plains area. He accepted the general principle of plant succession set forth by Sampson, Clements, and others; namely, that soil and vegetation develop concurrently. He strongly believed that condition of the soil was the basic consideration for judging condition of a range rather than the state of the soil's vegetal cover. For him, the fundamental objective of range management was achieving a condition of balance between

the biota, soil, topography, and climate. Hence the best management for an area of steeply sloping range would be different from best management for gently sloping or flat land. For the steep slope, good management was "far less a question of whether the biotic community is climax or subclimax . . . than it is a question of maintaining a vegetal cover of some kind on the slopes which will keep the soil in place."

The fundamental objective of range management, he and Croft (1944) wrote, "is or should be *balance*, the standard of satisfactory condition *a balanced complex*." Production of water, streamflow, and forage was a secondary objective. Having thus broadly stated fundamental objectives of range management, they described means by which the manager could determine the present condition of his range, by which he might determine whether it was better or worse than it had been, and by which from time to time he could tell whether its changing condition showed improvement or deterioration (Ellison and Croft 1944, page 26).

Ideally a manager should have available as basis for comparison some "natural" (i.e., ungrazed) area in pristine or near-pristine condition (Ellison 1949a). With this as a standard for comparison, he could determine how much vegetative cover (including species) and how much soil had been lost as a result of overstocking, overgrazing, trampling, and other types of abuse. In judging range condition, the manager should use this comparison as a *guide*, not as a *measure*, of an area's potentialities.

Ellison reiterated his earlier stand on the primary importance of soil: ". . . a basic criterion of range condition is degree of soil erosion, and a minimal requirement for satisfactory condition is normal soil stability." His second basis for judging range condition was the composition of the forage on that range, but he stated emphatically that soil stability was by far the more important. He exploded the myth that range condition could be attributed to weather. Climate was another matter — essentially, he said, "a constant"; hence its inclusion as one element of the range complex. Hence also his great interest in the climatic records begun at Utah Experiment Station some 30 years earlier and in the climatic studies that had been continuing since then.

In 1954, Ellison published a monograph in which he summarized the ecological information related to the subalpine zone of the Wasatch Plateau and reconstructed the character of the original vegetation there. He used data from some of the meter-square quadrats established by Sampson and charted at intervals since then; old photographs, range survey records, and data gleaned from many of his own studies provided additional useful information. To understand this vegetation it was necessary to work out salient characteristics of soil development and primary succession; consequently some of Ellison's conclusions conflict with those developed earlier by Sampson (1919b).

Ellison's major change in successional concepts was to identify the mixed upland herb association as the original vegetation on level areas and moderate slopes. Sampson had considered the "wheatgrass consociation" to be a seral herbaceous cover which was subclimax to the true spruce-fir climax. Ellison's mixed upland herb association is characterized by an abundance of tall perennial forbs such as tall bluebells (*Mertensia arizonica* var. *leonardi*), sweetanise, and western valerian (*Valeriana occidentalis*); and various grasses such as slender wheatgrass and mountain brome. Because of the heavy and widespread overgrazing, Ellison found very little area covered by this original vegetation. However, he described in detail the various seral communities and their successional patterns.

A posthumous article by Ellison (1960) brought together all of the known information about the influence of grazing on plant succession on rangelands. It reviewed the effects of grazing and artificial clipping on plant vigor and survival; it also discussed the effects of herbage removal on microclimate, soil moisture, and incidence of fire. In conclusion he stated one of the great unsolved problems of range management:

The fact that, under the apparent handicap of millennia of grazing, most of the dominant species of the world's herblands are palatable plants, not only to buffalo and elk but to domestic livestock, is very impressive indeed. It suggests both that the adaptive process in evolution is ex-

ceedingly complex and that perhaps we have been unable to discover a dependence of plants on grazing animals which is real and important. This is certainly to be reckoned one of the notable paradoxes of nature. Thus, in spite of all our study and thought, from the observations of herds-men before Abraham's time to the results of scientifically designed experiments in the present day, we have very little real comprehension of what is perhaps one of nature's simpler mysteries.

■ Climatic Studies

Climatic studies were started early in the life of the Utah Experiment Station, and throughout the Station's history three major types of such studies have been continued. In his report of the Station's first year of work, Sampson wrote: "In order to propose experimental work intelligently one of the essential and initial steps is to study the conditions which control vegetation, stream flow and the like." As a preliminary to the studies of erosion on the Wasatch Plateau, measurements and records of the temperatures of air and soil and of precipitation and soil moisture were made at 10,000 feet. Thus began the years of recording of temperatures and precipitation on Watersheds A and B and later on other areas. Records of temperature and precipitation on Watersheds A and B constitute the first major studies of climate in this particular area; of course they had immediate direct bearing on the erosion studies; additionally, over the long term they provided important information used in the plant studies that were part of the revegetation phase of the grazing and range program.

The several plant communities have their individual requirements for moisture, sunlight, warmth, etc.; so a second set of studies was undertaken at the Station to (1) obtain a comparison of the climatic requirements of the main plant communities and (2) determine quantitatively the relation between local environmental factors and plant growth.

In 1913, Sampson set up meteorological stations at elevations of 7,100, 8,700, and 10,000 feet in the heart of the oakbrush, aspen-fir, and spruce-fir associations, respectively (Sampson 1918a). At these stations the major climatic factors (air temperature, precipitation, evaporation, barometric pressure, wind velocity, and sunshine) were recorded so that many environmental characteristics of each type-zone were well known. Study of the influence of weather on the development of plants began in 1915 and continued through 1916. The plants used for study at each weather station were a pedigree strain of Canadian field pea, cultivated wheat, and native mountain brome. They were grown in potometers protected by screens. In the potometers two types of soil were used: infertile clay loam typical of areas where erosion and washing had diminished the humus and soluble salts, and fertile clay loam that had not been subject to erosion and washing.

This study produced voluminous and varied information about the three types of plants and about the climate of central Utah. Sampson's report also includes a wealth of information about techniques of the study and about capabilities and limitations of the equipment used in it. His correlations between environmental factors and plant growth and other physical activities were profitable reading for ecologists and botanists in his own time and are still informative a half-century later.

Sampson's study showed that growing seasons averaged 120 days in the oakbrush type, 105 in the aspen-fir, and only 70 days in the spruce-fir type. Average annual precipitation was greatest in the aspen-fir type but only slightly greater than in the spruce-fir association. Later studies by Lull and Ellison (1950), based on longer periods of time, indicated that precipitation increases with elevation; thus, the spruce-fir zone had the highest precipitation. Precipitation in the oakbrush type was barely half that in the higher elevation aspen-fir type (Sampson 1918a). Evaporation during the growing season was, as would be expected because of high temperatures and low humidity, greatest in the oakbrush type; but high wind velocity in the spruce-fir type (about 100 percent greater than in the types immediately below) resulted in evaporation comparable with that in the oakbrush. Both duration and

intensity of sunshine are practically the same at all elevations.

Costello and Price (1939) published results of much more elaborate studies that had extended over a longer time (1925-1934). The purpose of their Bulletin was to give detailed guidance in solving certain problems in range management — specifically to answer the persistent question: When is range ready for early season grazing? Costello and Price's study confirmed several of Sampson's main conclusions; namely, that:

1. Rate of maturity of plants decreases directly as heat units decrease at successively higher elevations.

2. Amount of water required to produce any unit of dry matter is greatest in the oak-brush zone, lowest in the aspen-fir zone, and intermediate in the spruce-fir zone; these relations coincide with the intensities of evaporation in the respective zones.

3. Total and average length of leaves and total dry weight produced are greatest in the aspen-fir zone and less in the other two zones.

4. Stem elongation is greatest in the oak-brush zone, intermediate in aspen-fir, and least in spruce-fir; this appears to be determined largely by temperature.

5. Production of dry matter appears to vary inversely with evaporation, but temperature also appears to be important.

One interesting and significant result of the Costello-Price study was discovery of the importance of the date of snowmelt in the spring. This date varies considerably from year to year, depending on depth of snow accumulation during the winter, temperatures during the melting period, and elevation. Progress of the entire growing season appears to be so closely related to this date that, given a 10-year average date for snow disappearance and the current year's deviation from that date, one can predict with surprising accuracy the dates when plant growth will start, when flower stalks will appear, when flowers will bloom, and when seeds will ripen. This is extremely useful, since the date when flower stalks appear indicates when a range area will be ready for grazing, and the "seed ripe" date is useful in determining when deferred grazing may begin. Seasons that begin early, late, or normal tend to remain so. Of

course, during early growth a plant may be thrown off schedule by some extreme variation of weather from the normal.

Costello and Price's system for predicting dates of successive stages of plant growth was based on regression equations, which in turn were developed from data recorded for individual species at different elevations through a series of years. They checked reliability in 1935 by observation of development of individual plants at 50 staked locations over a large area at the head of Ephraim Canyon at elevations between 9,000 and 10,000 feet. They found that rate of plant development varied within and between classes of vegetation and that variation between stages of development of forbs and browse was much greater than for grasses. Costello and Price also confirmed the observations of Sampson and Malmsten that for each 1,000-foot increase in elevation the date of vegetational readiness is delayed about 18 days on south exposures and about 11 days on north exposures; at high elevations this variation is reduced.

Even though subject to considerable error, the methods for estimating range readiness for spring grazing devised by Sampson, Malmsten, Costello, and Price were a great improvement over rule-of-thumb estimates that had been used previously.

■ Plant Nutrition Studies

During part of the same time that Price, Evans, Costello, and others were studying the influences of climate on plant development, Price and Edward C. McCarty⁹ were studying processes of growth and food storage for mountain brome, sticky geranium (*Geranium viscosissimum*), coneflower (*Rudbeckia occiden-*

⁹ McCarty was head of the Botany Department of Riverside Junior College in Riverside, California. During summer months of 1932-1936, Intermountain Station employed him as Associate Forest Ecologist to carry out growth studies on several mountain range forage plants.

talis), and slender wheatgrass. McCarty's studies of mountain brome demonstrated that its annual growth was in well marked cyclical stages. He also showed that growth rates vary at different times during a season and that a plant's supplies of nutrients decrease whenever the plant speeds up its growth (McCarty 1938).

McCarty pioneered physiological research concerning food storage and depletion related to phenology and clipping. His work has been widely quoted in range management literature and has inspired much similar work on other species.

The pattern of growth of mountain brome was characteristic in a general way for other forage plants found commonly on high-elevation range. The final report on these studies, a Bulletin published after McCarty's death (McCarty and Price 1942), carried specific recommendations for management of range on the Wasatch Plateau and similar areas. Grazing such areas, this report advised, "should be so coordinated with the critical growth and developmental stages of the principal perennial forage plants that the plants may assimilate and store sufficient foods to maintain growth and produce herbage for forage in subsequent years." Harvesting plants during their normal period for storing food prevents this storage; so grazing should be slackened then. Early grazing (plants 4 to 6 inches high) and grazing when herbage is dry or drying seemed to them to be well timed, but they cautioned against grazing so early that plants would be uprooted and trampled. They advised moderate grazing of mountain brome and slender wheatgrass (to a height of 3 or 4 inches at approximately monthly intervals) as "the key to practical and sound continued use of the annual forage crop produced on high western mountain ranges." Finally they restated one of Sampson's ideas and they urged rotation of grazing so that no given area would be grazed at the same time in successive years. "This provision," they wrote, "will allow for the production of seed and the reseeding of the range previously found to be necessary and may also obviate the necessity of slackened grazing during the critical periods of plant growth." This is one of the basic principles of the rest-rotation grazing systems now being widely applied.

■ Silvicultural Studies

Though Raphael Zon was one of the first men to approve establishment of the Station and some of the early studies suggested by Sampson, silvical research has never been a major activity at the Great Basin Station. As early as 1917, the Annual Report of the District Investigative Committee¹⁰ for District Four stated: "It has been the feeling from the beginning that the Utah Station is not located advantageously for the prosecution of the greater part of our silvicultural investigations which are to a large extent local and not representative of those parts of the District in which silviculture is of primary importance. Our most important forest types are yellow pine, Douglas fir and lodgepole, and of these yellow pine is the most important." The committee concluded by recommending establishment of a silvicultural experiment station in central Idaho. This statement contrasts sharply with W. R. Chapline's comment in a letter to The Forester in 1922:

The [Great Basin] Station is fortunately situated, in that it is located where the northern and southern flora of the western United States meet, so that conditions that cover a wider area perhaps than any other single Station could cover are found here.

However, the Utah Experiment Station was involved in one major silvicultural project that still has interest even though it was terminated many years ago. This was a study of the possibility of growing merchantable timber, specifically ponderosa pine, in the oak-brush zone.

¹⁰Members were L. F. Kneipp, District Forester, Chairman; W. N. Sparhawk, Forest Examiner, Secretary; C. B. Morse, Forest Supervisor; Homer E. Fenn and C. G. Smith, Assistant District Foresters; and Arthur W. Sampson, Director of Utah Experiment Station.

An ecological phenomenon that intrigued many early foresters was the so-called "pineless belt" between west central Montana and the Gulf of California. This area, several hundred miles wide in some places, is not devoid of pine but it naturally supports very little ponderosa (*Pinus ponderosa*) — or western yellow pine, as it was formerly known. It is a brushland belt running through the center of the usual habitat of ponderosa pine (Baker

and Korstian 1931). The brushy vegetation is of several types found commonly throughout mountainous areas in northern and central Utah, southeastern Idaho, and western Wyoming that would normally be expected to support forests of ponderosa pine. The Utah Experiment Station was well within this belt, and the Transition zone in Ephraim Canyon supports abundant growth of oakbrush (fig. 13).



Figure 13. — The oakbrush zone in Ephraim Canyon where F. S. Baker and C. F. Korstian planted hundreds of seedlings of ponderosa pine and other conifers.

In this oakbrush zone, F. S. Baker and Clarence F. Korstian carefully studied climatic, soil, and other factors that might account for the absence of ponderosa. At the same time, they established another study area, some 25 miles distant on the east side of the Wasatch Plateau, where ponderosa grows in commercial stands. Baker's diary from February 7 to October 5, 1916, records planting of some 4,500 trees within a 2-month period. Of these, 2,000 were ponderosa pine; the rest were lodgepole (*P. contorta*) (400), Douglas-

fir (*Pseudotsuga menziesii*) (1,000), Norway spruce (*Picea abies*) (700), and western larch (*Larix occidentalis*) (400). At the "oak-brush station" (apparently the area now labeled Plant Development Station 2) and in the adjacent area one can today see many trees from these early plantings. They vary from 30 to 50 feet in height, have diameters of 8 to 10 inches, and look reasonably thrifty. A few may be seen beside the Ephraim-Orangeville Highway (fig. 14), as many of them are not more than 100 yards from the road. Close in-



Figure 14. — Ponderosa pine trees planted by F. S. Baker about 1915 in the oakbrush zone, as seen from the Ephraim-Orangeville road in 1970.

spection of the plantings, though, reveals no regeneration.

Baker and Korstian reported that distribution of rainfall during the summer months in these brush areas in Utah "is notably different from that either to the north or south;" also that "deficiencies in July and August precipitation, combined with the fact that the rainfall usually culminated in August shortly before the early autumn frosts occur, make it impossible for the species to reproduce." They noted further that "the generally calcareous, heavy, fine-grained soils of the brush lands are prevailingly unsuited for western yellow pine." They were convinced that distribution of rainfall primarily determines the "pineless belt" and that details of its boundaries resulted chiefly from local differences in soils. The intense competition from the established brush cover was another factor limiting good growth of ponderosa pine.

F. S. Baker also did a great amount of work on aspen. Sampson (1919a) did some early work on aspen silviculture but it was mainly incidental to the study of the effect of grazing upon aspen reproduction. Baker's (1925a) major publication on the subject was the first to describe the phenology, growth, form, root systems, and the climatic, moisture, and soil requirements of aspen in detail. It was also the first comprehensive work on growth, yield, and management of aspen in the West. A major part of the publication was directed to the rate of growth and yield of aspen on different sites as a basis for management.

As part of his study, Baker established an elaborate set of permanent plots to determine if aspen timber production could be increased by thinning. In general, he found that thinning increased the production of wood in the form of sprouts and young trees but did not appreciably increase growth rates of larger trees. The detailed records on these permanent plots are invaluable historical base data on the ecology of aspen and are continuing to be used in current research. In 1970, Kimball Harper of the University of Utah and Robert Pfister of the Intermountain Station remeasured the trees on these plots to determine the

rates of growth and the mortality of the aspen trees.

Baker and other early workers recognized that the aspen type is perpetuated by fire and, because of prevalent natural fires, aspen has occupied many sites for very long periods of time. In the absence of fire, aspen is succeeded by conifers. Baker discussed the relative values of aspen and conifer on the same site. Based on the economics of the time he concluded that income from aspen would be lower than from conifer and that "there can be no point, therefore, in trying to maintain an aspen management type." In recent years the validity of this conclusion has been questioned by many who feel that the multiple benefits of aspen, including grazing for livestock and game, habitat for many birds and small mammals, fire resistance, and esthetics, outweigh the value of conifers for timber production on many sites.

Korstian, like many other close observers of plant life in mountainous areas of the West, noted the striking zonation of vegetation in a regular series of altitudinal belts in Ephraim Canyon and elsewhere. This altitudinal zonation, he believed, is important to the silviculturist and to the range management specialist because many of the problems of the growth and regeneration of forests and the maintenance of range can be solved best through determination of the soil and climatic requirements of the different species in each zone, a point well demonstrated by the ponderosa pine study just described. In reforestation, Korstian (1924b) wrote that success depends on knowing the causes of successful growth and establishment of individual species and likewise knowing the causes of failure or partial failure of other species in the same environment. Since the problem appeared to be based on moisture requirements and availability, he launched a study of the density of cell sap in a variety of plants, including trees, found in several altitudinal zones from 4,500 feet to the summit of the Wasatch Mountains. This study, he believed, had implications for both silviculture and range management. However, despite the considerable detailed work, its results never were put to much practical application.

■ Rodent Studies

From time to time, reports of experiments refer to rodent damage — occasionally to "severe" rodent damage, sometimes to "significant" or even "excessive" damage — but they seldom particularize. One unidentified author noted that rodent damage in the oak-brush zone in 1932 seemed excessive, but he did not tell what kind of rodent was guilty. All sowings and plantations in the nursery that year were cut off by rodents, and this just before seed maturity, so that it was impossible to collect seed that season. In an aspen area, rodents cut about 90 percent of crested wheatgrass, and at Major's Flat they cut all grasses from 90 to 100 percent. Sometimes this author named pocket gophers; occasionally he specified mice or voles.

Gopher damage was of several sorts: some was consumption of roots, plants, or plant bases for food; some was the creation of mounds on the soil surface. Where workings were heaviest, there was usually a change in plant cover to a lower weed stage. Douglas knotweed (*Polygonum douglasii*) and ground-smoke (*Gayophytum ramosissimum*) seemed to become established early on disturbed earth. One may infer that Ellison's interest in damage by rodents stemmed from his conviction of the importance of soil condition as a fundamental part of the health of the range. He seems to have been the first to give serious thought to the questions of what kinds of damage rodents did to the range, and in what amounts.

When Ellison began serious study of gophers (chiefly *Thomomys talpoides moorei*) about 1940, he was aware of the divergent opinions about gophers' influence on the range (Ellison 1946). Some thought the gopher was a necessary part of Nature's economy: presumably, he deepened and fertilized mountain soils, and his winter casts might check erosion and overland flow of precipitation. But others contended that gopher diggings were a prime cause of accelerated ero-

sion. As observers' opinions varied regarding the net effect of gopher diggings, so did their estimates of volume of earth these animals moved. Ellison's measurements in 1941 indicated annual soil displacement at 5 to 6½ tons (4.6 to 6.2 cubic yards) per acre. In 1942, serious study of gopher activity was begun by establishing a 4-acre, rodent-proof fenced plot on the summit of the Wasatch Plateau. This study was cooperative with the Fish and Wildlife Service and aimed to determine the effects of gophers on vegetation. Annual trapping periods in July and September, directed by C. M. Aldous, Biologist with the U. S. Fish and Wildlife Service, reduced populations from an average of about 24 per acre to from two to eight per acre (Ellison and Aldous 1952). Total effect of gophers on vegetation appeared to be slight at most. Common dandelion (*Taraxacum officinale*) decreased where they were present, but mountain dandelion (*Agoseris spp.*) did not. Grasses and sedges (*Carex spp.*) appeared to increase slightly. On areas subject to compaction under livestock grazing, gopher work seemed to help keep soil loosened.

Density of gopher population, like volume of their work, varied by location. Gophers were not active in timber or in brush; they worked most in the low herb type. Ellison's observations indicated that gopher tunnels seemed not to be a source of erosion from either snowmelt or torrential summer rains. On erosion pavement and other areas where topsoil and cover had been lost, their surface mounds seemed to provide a relatively favorable seedbed.

Ten years' observations and measurements provided a body of documented information about gopher influences on mountain range-land, but the question whether the total effect of gopher presence was deleterious was still open for argument. C. M. Aldous, who participated in the experiments at Great Basin Station, wrote after 14 years: "It is an open question whether gophers are responsible for bringing about or creating poor range conditions, or whether ranges in poor condition tend to attract pocket gophers" (Aldous 1957).

COOPERATIVE PROJECTS

Research organizations frequently require help from similar units and reciprocate by giving special help of their own. Cooperative projects with the Utah Division of Wildlife Resources, the Bureau of Sport Fisheries and Wildlife, and the Agricultural Research Service have been mentioned previously. Many other types of cooperative projects have also taken place at the Great Basin Station.

From time to time, Station personnel have responded to requests from schools and service clubs to discuss Forest Service research generally or Great Basin projects specifically. For several summers following World War II, the Station was locale for a 2- or 3-day outing for 4-H clubs in Sanpete County. Station facilities have been used for numerous training sessions for Forest and Region personnel. A 2-week Range Research Seminar (July 10-22, 1939) was attended by nearly 60 range management research specialists and administrators from all western regions and from

Washington, D. C.¹¹ Over the years it has participated in occasional research projects of the Agricultural Experiment Station of Utah State University. The Station's long continuous record of climatic data for Ephraim Canyon and the Wasatch Plateau frequently has proved invaluable.

Since 1966, Intermountain Station has participated in a cooperative project in teacher training sponsored by the Utah State Department of Public Instruction. The Intermountain Region of the Forest Service also has participated actively in this development of instructional programs and in directing field trips and related activities. The project essentially is 5-day workshops designed to prepare teachers in elementary and secondary schools to teach fundamental concepts of conservation and of improvement in quality of the environment. The 5-day sessions are planned for groups of about 40 teacher-students, and the number of sessions per summer has varied from one to four.

Instruction includes demonstration of the function of vegetal cover in reducing overland flow and stabilizing soil, identification of useful plant species, identification of numerous birds and mammals found in Utah wildlands, and demonstration of effective techniques for teaching fundamental conservation concepts to young people in the elementary and secondary schools.

Response by the Department of Public Instruction and by the teachers has been enthusiastic. An interesting and unexpected byproduct of this project has been the changing of many teachers' image of the Forest Service. Until their direct contact with it at the Great Basin Station, many of them had presumed the Forest Service was largely if not solely a law enforcement or fire protection agency. They have been literally amazed to learn about the Forest Service activity in research and management relating to recreation, wildlife habitat, watershed protection, livestock forage, timber production, and other uses and values of wildlands.

¹¹See *Proceedings of Range Research Seminar*. Forest Service, U. S. Department of Agriculture. 414 p. (n.d.) This volume contains 35 professional papers and discussion of them.

APPLICATIONS

The "proof of the pudding" principle applies with full validity to research; but here the "proof" is in the use or application. Results of much of the research at Great Basin are now in use or have been used for many years; but it is virtually impossible to document details or specific instances of adoption of individual results. It is certain that research pioneered and carried out on, or headquartered at, the Great Basin Station has touched every aspect of range management. Early work proved conclusively the relationship between overgrazing and depletion of the vegetal cover and destructive flooding. McCarty's work on food storage cycles of plants was the first research to provide a scientific basis for management and utilization of forage plants. Ellison's work on condition and trend criteria was quickly incorporated into National Forest Administration range allotment analysis procedures and is the basis for many criteria in use today by many land management agencies. Seeding work done by Plummer, both on high mountain areas and in lower oakbrush and pinyon-juniper areas, has provided information on adapted species that has been widely used by all land management agencies in their revegetation work.

The principle of deferred-and-rotational grazing, developed and advocated by Sampson, Forsling, and numerous successors has been a subject for continuing study and re-

finement. Many recent studies of deferred and rotation grazing have been made at Forest and Range Experiment Stations throughout the West. These practices have proved useful, and numerous variations have been made to the original systems; but there is no way of knowing how many range managers use them in any form, much less how they learned about them. Rest-rotation grazing (Hormay and Talbot 1961), modifications of which are so widely being put into practice now on public and private ranges, is but a variation of the deferred- and rotation-grazing schemes developed by Sampson.

The ideas of the possibility of and necessity for management of rangeland were spreading about the time the Utah Experiment Station was established. Land-grant colleges began by giving single courses in the subject; as more needs became evident and more information was developed, the number of courses increased, and what had been one man's specialty became a department; of course the ultimate development has been that both bachelor and graduate degrees have evolved, with range management as a major program. Utah Agricultural College (now Utah State University) offered its first course in range management in 1914 and established a curriculum in it in 1928. Montana State University offered its first course in range management in 1915, and Colorado Agricultural and Mechanical College followed in 1916. Courses in range at the University of Idaho and the Oregon State Agricultural College were taught first in 1917. Washington State College followed in 1919; University of California offered its first course in range in 1920 but did not establish a curriculum in it until 1953. The succession of years when courses were first offered reveals clearly that the idea of training young men in this subject had caught on.

Sampson's prolific writing about range management and related subjects continued after he left the Great Basin Station to teach at the University of California. Within a few years he published three books that received wide acceptance as textbooks and reference works (Sampson 1923b, 1924, and 1928). These books were based largely on research at the Great Basin Station and they became the

"bible" for range managers at that time because no other texts were available. Of course, with the passage of time and the proliferation of college courses in range management, the number of books on the subject also increased.

The early plant studies, begun as part of the projects in natural and artificial reseeding, developed into rather elaborate studies of fundamental plant behavior that extended the bounds of early ecological knowledge. These have been discussed already in the section "Ecological Endeavors."

To a degree, what happened in the development of range management was paralleled by the development of studies of watersheds, their management and maintenance. Treatments and studies of Watersheds A and B and of the nearby Carrying Capacity Pasture established beyond question the necessity for having certain minimal vegetal cover on high-elevation rangeland to prevent overland flow, flooding, and erosion following typical high-intensity summer storms. Principles discovered by study on the Wasatch Plateau were demonstrated effectively by Reed W. Bailey and others in treatment of the Davis County watersheds after disastrous mud-rock floods in the decade of the 1930's. The work at Farmington, like that at Ephraim, has generated considerable publication, and the Davis County Experimental Watershed has been visited by hundreds of scientists from the United States and numerous other countries who needed to learn fundamentals of flood prevention. We cannot say certainly whether development of the science of watershed management preceded the development of range management, but we may observe a certain paralleling. In central Utah, realization of the problem of watershed management appears to have preceded realization that range management was the key to its solution.

The management of mountain rangeland for the benefit of wildlife or for use by both wildlife and stock might appear to be a project of more recent origin. However, it was in the thinking of range management people by the decade of the 1940's. In his presidential address at the second annual meeting of the American Society of Range Management, Joseph F. Pechanec said, "One of the greatest challenges we have is to determine how by re-

search, and to prove by practice that grazing livestock and big game in our forests and on our grasslands need not necessarily be damaging to the land, ruinous to the watersheds, and destructive of civilizations." Wildlife management, like range management and animal husbandry, has found its way into college curricula. As hunting pressures and interest in all forms of wildlife have increased, so has the need for improvement of wildlife habitat; hence the economic and political pressure for maintenance and improvement in game range. Study of game range and devising means for its improvement have been pioneered at the Great Basin Station, and application of the results of these studies has been rapid and successful, as has been mentioned above.

Continuing ecological studies at the Great Basin Station understandably have had important use in National Forest administration. What has been learned about total range, about condition and trend criteria, and about characteristics of numerous range plants has influenced policy in range administration. It has made the determination of the grazing capacity of allotments a matter of informed judgment and skill rather than a haphazard rule-of-thumb procedure. These studies have enabled Forest Service personnel and others to judge with some accuracy when grazing may safely begin in spring and when, in summer or fall, grazing should be stopped. Results of these studies have been used in training young foresters, and publication of these results by the Forest Service and in professional and trade journals has disseminated this information far beyond the borders of the United States.

Although much research at the Great Basin Station could be classified as "basic" or "fundamental," the studies have all been oriented to practical use. The information developed at the Great Basin Station has been applied in conservation of a great natural renewable resource, in determination of Forest Service policy for the administration of range areas and watersheds, and in training young foresters in certain fundamentals of their job. Research at the Great Basin Station has been anything but a narrow, restricted, "ivory tower" affair; rather it has been as wide open as the sunny hillsides and plateaus on which it has been done.

FUTURE PLANS

The Order Establishing the Great Basin Experimental Range assumes continued research that will have application in land management for many years ahead. The list of projects proposed for future study there includes:

1. Ecology and management of pinyon-juniper, spruce-fir, mountain herb, oak-brush, aspen, and associated plant communities and their relation to various environmental factors, particularly soils and weather.
2. Improvement and management of big game habitat.
3. Selection and breeding of improved shrubs, evaluation of promising selections, development of efficient seed-production technology, and development of effective procedures for shrub establishment in forest and range environments.
4. Wildlife-livestock relations in multiple use management.
5. Range-watershed rehabilitation.

6. Water-yield improvement through vegetative manipulation and structural measures.
7. Silviculture and management of aspen and associated conifers in relation to forage, water, and other multiple use values.
8. Forest recreation planning and management.

Other plans not mentioned in the Establishment Order include interdisciplinary studies in the functioning of the aspen ecosystem. Aspen is an important type in the mountains of Utah and surrounding States and furnishes valuable cover and forage for game and livestock, important watershed protection, some timber, and is an important part of the mountain scenery. Because of fire protection many aspen sites are now being invaded by conifers. The dynamics and economics of this change need to be determined so the land manager can intelligently either permit or prevent the replacement of aspen by conifer. The Great Basin Experimental Range will be an ideal place to conduct aspen ecosystem studies because of the abundance of aspen and because of the long history of vegetation and climatic records in the aspen as well as in other vegetation types.

Nearly a hundred meter-square quadrats are on or in the vicinity of the Great Basin Experimental Range; many of them were established by Sampson in 1913 or 1914 and have been sampled at irregular intervals since then. These records of vegetation change, along with corresponding climatic records, form a pool of data that will be invaluable for further study of the ecology of these plant communities and their response to changes in the environment.

The Intermountain Forest and Range Experiment Station is seriously considering possibilities for developing a visiting-scientist program that would attract outstanding university scientists to the Intermountain area for the summer months. The Great Basin Experimental Range has excellent possibilities for this purpose; it is easily accessible; it has a pleasant summer climate; living quarters are comfortable and attractive; and limited facilities for some kinds of laboratory work are immediately available.

RESEARCH PUBLICATIONS

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The Forest Service has long maintained that no research project is completed until its results have been formally published or otherwise made available to workers. Over the 60 years since establishment of the Utah Experiment Station the volume of publication based on results of studies on the Wasatch Plateau and in Ephraim Canyon has been substantial. The bibliography that follows is a selective list of publications known to be based in whole or in part on research done there.

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Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with University of Montana)

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Photo on back cover: — Beck's Ridge and head of Seeley Creek Canyon, site of many experimental plots for plant studies by Utah Experiment Station personnel.



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